SYNOPSIS V1.0:

Single Event Latchup Test Results IBM 5HP CMOS Ring Oscillator

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I. INTRODUCTION

This study was undertaken to determine the radiation-induced performance degradation characterization of the IBM 5HP CMOS Ring Oscillator (RO) supplied by Auburn University, this work is funded by NASA Electronic parts and packaging Program's Electronics Radiation Characterization Project and Defense Threat Reduction Agency.

We have two goals:

- Determine Single Event Latchup (SEL) sensitivity.
- If SEL does occur, determine if it is destructive or non-destructive.

The testing was done in air at Texas A&M University. The power supply current was monitored for large increase and the device functionality.

II. DEVICES TESTED

The ring oscillator designed in IBM 5HP CMOS process. Auburn University provided the samples. There were be two ROs per package, a RO #1 and a RO #3. RO #1 period is ~ 8.8 ns, and RO #3 is 7.5 ns. The package is such that there is line-of-site access to the die. Figure 1 shows the package and Table 1 gives the pinouts. (The table 2 below describes each DUT package.) Package 1,4 and 6 were selected for testing.

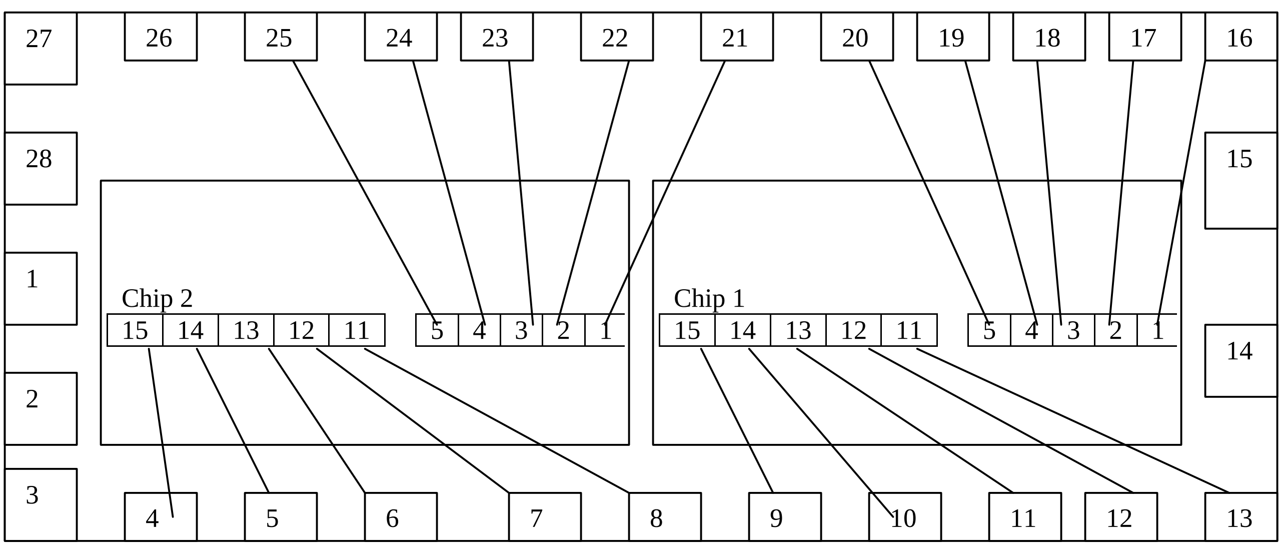


Figure 1. Package showing four RO.

Table 1. Chip padouts, Figure 1 gives the correlation between pad and pins

Each oscillator has the following pad definitions :	Comments
Pad 1 (11):VDD;	
Pad 2 (12): Inhibit;	In general, the inhibit is tied with VDD – comment from Shiming Zhang (AU).
Pad 3 (13): Ground;	
Pad 4 (14): Output;	
Pad 5 (15): VDD buffer;	

Table 2 Device numbering, markings, and pre-test summary (Shiming Zhang - 5/31/01)

Package	Chip	Oscillator	Status
Package 1	Chip 1	Oscillator 1	Not Working
		Oscillator 3	Good
	Chip 2	Oscillator 1	Good
		Oscillator 3	Good
Package 2	Chip 1	Oscillator 1	Not Working
		Oscillator 3	Not Working
	Chip 2	Oscillator 1	Good
		Oscillator 3	Good
Package 3	Chip 1	Oscillator 1	Good
		Oscillator 3	Good
	Chip 2	Oscillator 1	Not Working
		Oscillator 3	Not Working
Package 4	Chip 1	Oscillator 1	Not Working
		Oscillator 3	Good
	Chip 2	Oscillator 1	Good
		Oscillator 3	Good
Package 5	Chip 1	Oscillator 1	Not Working
		Oscillator 3	Good
	Chip 2	Oscillator 1	Not Working
		Oscillator 3	Good
Package 6	Chip 1	Oscillator 1	Good
		Oscillator 3	Good
	Chip 2	Oscillator 1	Good
		Oscillator 3	Good
Package 7	Chip 1	Oscillator 1	Not Working
		Oscillator 3	Not Working
	Chip 2	Oscillator 1	Good
		Oscillator 3	Good

III. TEST FACILITY

Facility: Texas A&M University Cyclotron
Flux : $3.0x10^4 – 1.2x10^5$ particles/cm^2/s.
Particles: normal incident Linear Energy Transfer (LET). Other LETs can be achieved by rotating the angle of incidence.

Table 4. Ions used during testing

Ion	LET ($MeVcm^2/mg$)
Kr	20
Xe	40.5

IV. TEST METHODS

Case Temperature: 60-63 C
Test Hardware: A custom test set was used to supply a nominal input levels to the Devices Under Test (DUTs) and monitor the DUT output and power supply currents for changes resulting from the radiation exposure. Figure 2 gives a block diagram of the test set configuration. A Shunt meter is used to measure the current on each of the VDD Buffer and VDD inputs. Channel 1 of the power supply is connected to the VDD inputs and Channel 2 is connected to the VDD Buffer inputs. The 4 outputs of the ring oscillator are monitored by an oscilloscope and checked for transient using the limit test program in Labview. A 4 GHz digital oscilloscope (Tektronix TDS784C) was used to monitor the DUT functionality during the irradiation. The scope was triggered to capture a trace when the DUT output deviated from the expected value. The trace was saved for later processing. The hardware is capable of capturing at least 4 traces per second.

The setup allowed for heating the DUT via a thermal strip, temperature monitoring was achieved using a thermistor.

A Hewlett-Packard 6624 power supply supplied power to the DUT. A custom test set was used to supply the DUT these input levels. The output is a period of ~ 8.8 ns (RO #1) and 7.5 ns (RO #3). The test setup monitored the DUT outputs for functionality before, during and after the irradiation. The test set monitored and record the bias supply current. Power supply current history files were generated for each DUT throughout the entire exposure, the measurement accuracy was on the order of a milliamper.

If an SEL is detected, the test setup (actually done in software) would of attempted to prevent a destructive failure by turning the supply voltage. The test setup will be such that this rapid-halt mode could of be disabled to test for destructive failure.

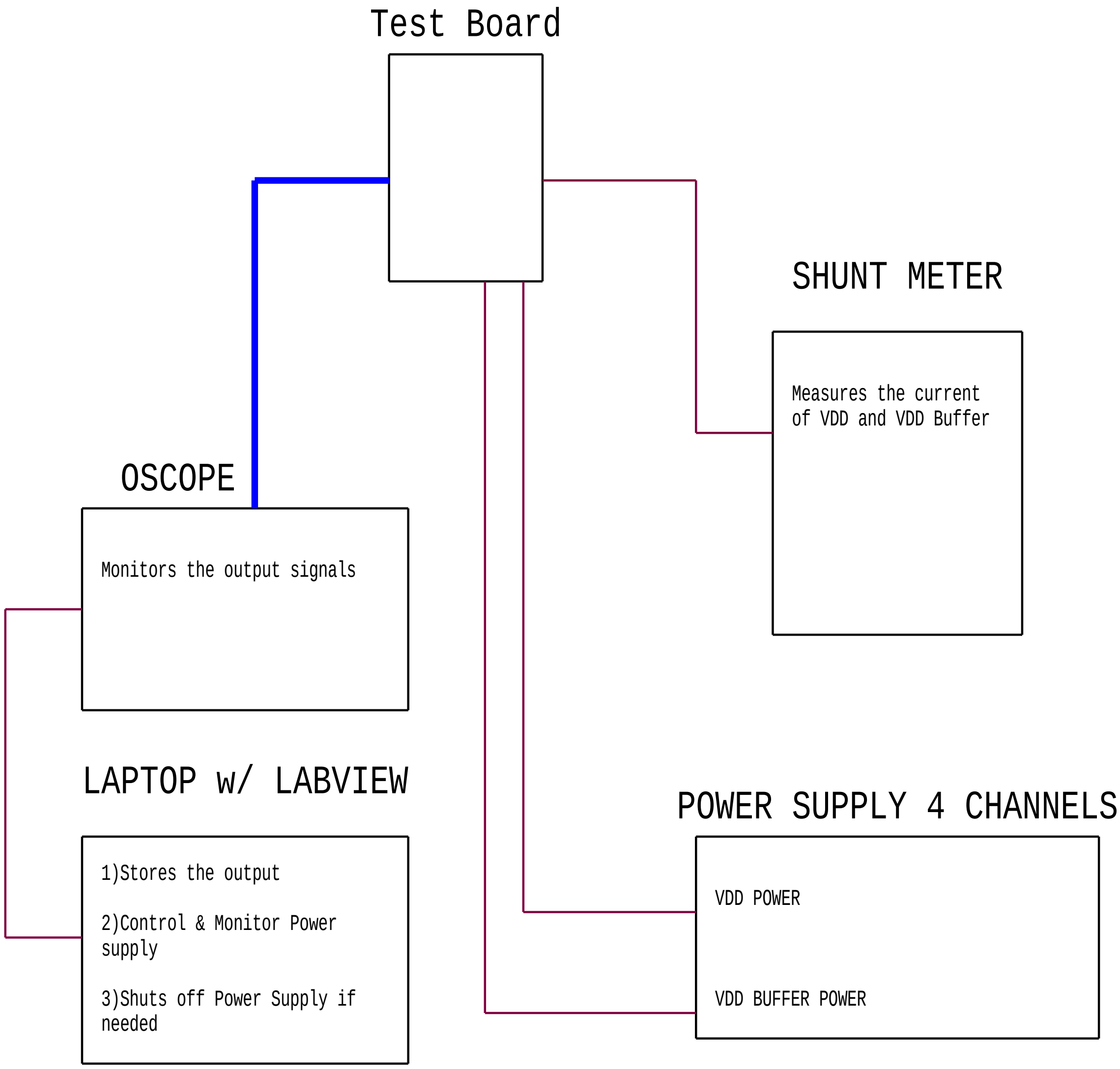
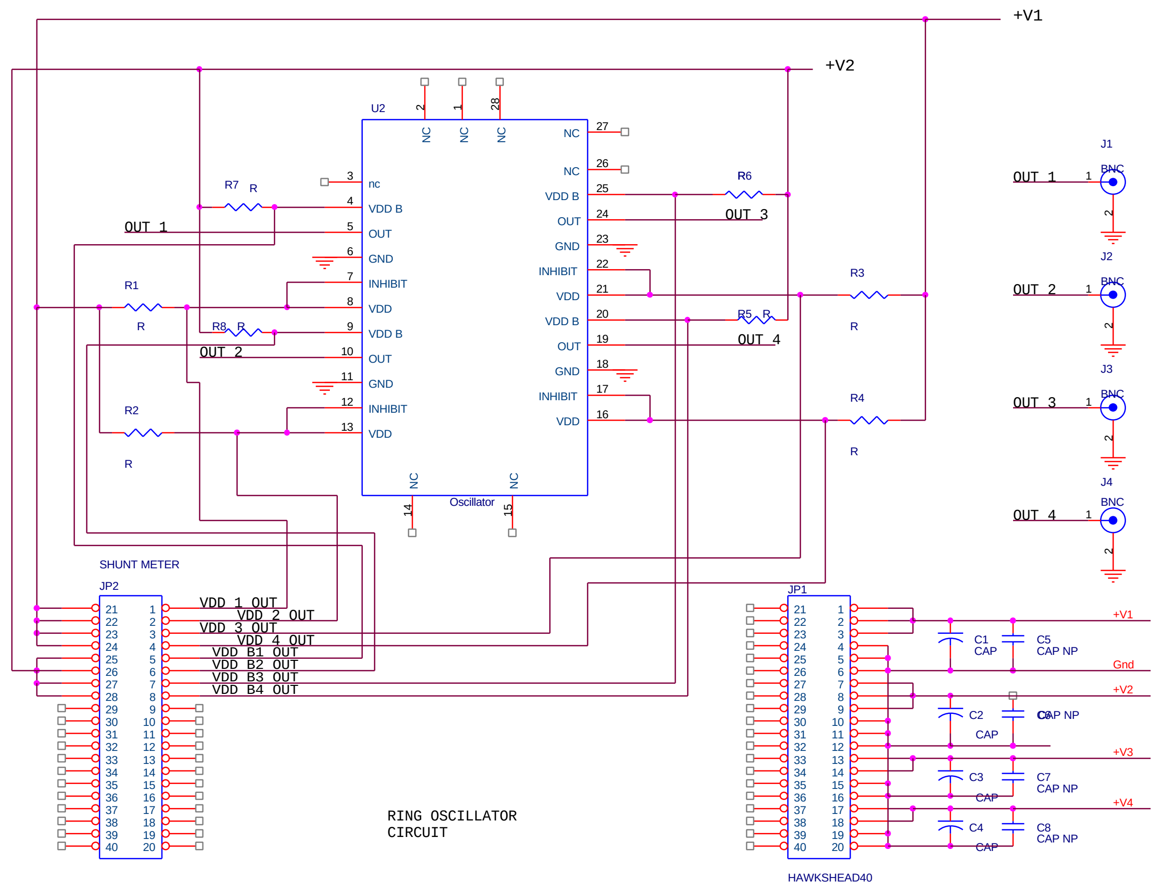


Figure 2. Test setup hardware configuration.



Software: Customized LABVIEW® software provided a user interface to control signals to the DUT. The software also automatically monitored the DUT output (via a trigger from the hardware) and supply currents, a Single SEL file history was generated. The software automatically turned off the DUT power supply when the current exceeded a user-defined value, i.e., limiting current (I_L).

Test Techniques: Tests were performed on package number 1, 4 and 6 (see Table 1) to measure SEL susceptibility as a function of particle LET for various DUT configurations. The test setup allowed for monitoring the temperature, all SEL testing was done at 63 C. The supply bias (VDD) and Inhibit bias conditions were 4V. VDD buffer was set at 3.6V. All supply currents stayed below the nominal operation conditions for the entire test cycle.

The device was deemed to have experienced an SET when the output deviated from its expected value by more that 0.5 V. The number of deviation during an irradiation was not tabulated.

SEL susceptibly of the DUTs were determined by monitoring the supply current for current increases larger that I_L. For all cases I_L was set to 17 mA for the positive and negative power supplies. Device functionality was monitored by observing the output of the RO during all testing.

Irradiation level should be chosen from Table 4 based on the response of the device and the current increase due to TID. The information below assumes that DUTs PA1(300 inverters), PA4(225 inverters), and PA6 (225 inverters) are used in the testing. It also assumes that the physical inverter area is 0.25 μm x 5.0 μm. The exposure level was $5x10^7$ p/cm^2 for all LETs to ensure that the inverters will be struck by at least 500 ions.

V. RESULTS

Heavy ion testing was carried out on package number 1, 4, and 6 conditions to a fluence of $5x10^7$ p/cm^2 for LET of 20, 40.5 and 81 MeV cm^2 / mg. None of the ROs experienced SELs for the electrical conditions described above.